TISA Working Group Report

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Joint CERES-GERB and SCARAB Earth Radiation Budget workshop
7-10 October 2014 Toulouse (France

TISA GEO Edition 4 improvements

- 1-hourly GEO imager fluxes and cloud retrievals
  - Ed3 3-hourly GEO
- 4-channel GEO cloud retrievals
  - Ed3 2-channel GEO cloud retrievals
- GEO imager semi-automated bad scan line detection and removal algorithm
  - Ed4 has 7 times the number of GEO images
  - Ed3 post 2012 human visual detection routine applied before cloud retrieval processing
  - Ed3 pre 2012 cloud and flux retrieval error prompted bad scan line removal
- MTSAT-1R visible imager point spread function correction applied
  - Mitigated SW flux and cloud property discontinuity in the TWP GEO domain compared to Ed2

TISA GEO Edition 4 improvements

- All GEO imagers calibrated ray-matched against Aqua-MODIS collection 6 calibration, stable to within 1%/decade (Ed4 final Nov 2013)
  - Used SCIAMACHY spectral band adjustment factors to remove spectral band differences between GEO and MODIS
  - Validated calibration with desert, DCC, and Terra-MODIS scaled to Aqua-MODIS ray-matching
  - Ed3 relied on the Terra-MODIS collection 5 calibration, Terra had calibration anomalies in Nov. 2003 and Jan. 2009
- GEO LW and CERES-WN flux improvement
  - Normalize the GEO imager 11µm and 6.7µm temperatures with Aqua-MODIS
  - Apply Aqua-MODIS 11µm (WN) and 6.7µm (WV) to CERES LW flux model based on SSF, Terra-MODIS has noisy WV
  - 5° b 5° LW GEO/CERES normalization (similar to SW)
  - Ed3 11µm to LW apriori parameterization and instantaneous normalization

TISA Edition 4 improvements

- GEO SW flux improvements
  - Computed 32 spectral band radiances as a function of surface type, cloud optical depth, PW and cloud height. The spectral radiances are easily convolved with the GEO imager spectral response
  - Over oceans convert GEO visible radiances directly to broadband
- SSF1deg and SYN1deg products are both GMT based
  - Use GMT hourly integrated SZA, rather than mid-hourly snap shot SZA (no daily SW adjustments needed)
  - No twilight included (only in the net balanced EBAF product)
- Solar incoming is based on SORCE V-15 absolute calibration
  - RMIB composite (DIARAD/VIRGO) solar incoming used after July 1, 2013 to present
  - Any SORCE/RMIB version calibration updates are normalized between March 2003 and Feb 2008 SORCE V15
  - Solar incoming coding errors removed

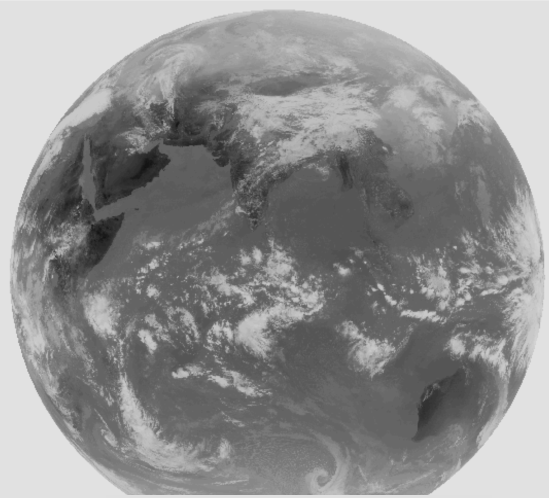
TISA Edition 4 improvements

- SYN1deg Ed4 HDF 1-hourly, 3-hourly, daily and monthly products
  - Incorporate into CERES ordering tool to easily subset by parameter and location
  - Ed3 3-hourly, monthly 3-hourly, monthly, (no daily, except on subsetter)
- SSF1deg and SYN1deg HDF file formats
  - Parameter naming convention consistent across temporal resolutions and between SSF1deg and SYN1deg, facilitates comparisons between the two products
  - Unique shortened parameter code friendly SDS names and added long name attributes
  - HDF4 easily convertible to netCDF and HDF5 and compatible with most HDF visualizers (Panoply)
  - New HDF format allows for QC before sub-setting capabilities are implemented, standardized CERES ordering tool selection pages and netCDF conversion for ordering and visualization for validation

INSAT-3D

- INSAT-3D 6-channel GEO imager launched on July 25, 2013
  - NOAA currently obtaining images from ISRO and are allowed to redistribute (Shoba Kondragunta contact)
  - Working with McIDAS to ingest INSAT-3D (Sanjay Limaye contact)
- Other GEO imagers over Indian Ocean
  - Kalpana, 74°E, 2002, 3 channel (available in McIDAS)
  - FY2D, 86°E, 2006, 5 channel (available in McIDAS) unstable IR calibration and visible stray light
  - INSAT-3A, 93.5°E, 2003, 3-channel
  - Met-7, 57°E, 1997, 3-channel (available in McIDAS), The CERES designated GEO
- Meteosat-11 launches in 2015
  - A very remote possibility that Met-8 will replace Met-7 over the Indian Ocean, also has a GERB instrument

Central wavelength	Spectral interval
0.65 µm	0.55 - 0.75 µm
1.625 µm	1.55 - 1.70 µm
3.90 µm	3.80 - 4.00 µm
6.8 µm	6.50 - 7.10 µm
10.8 µm	10.3 - 11.3 µm
12.0 µm	11.5 - 12.5 µm

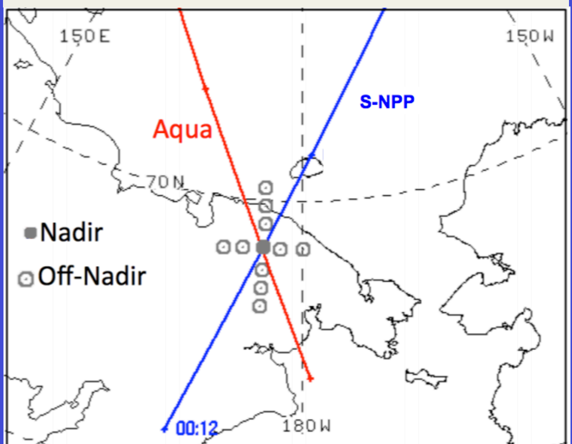


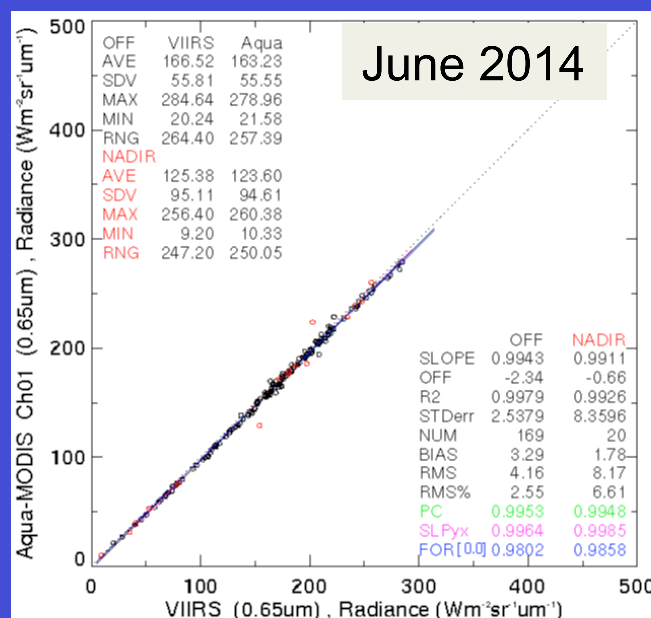
Feb 28, 2014, 9GMT

Aqua-MODIS to VIIRS radiometric scaling

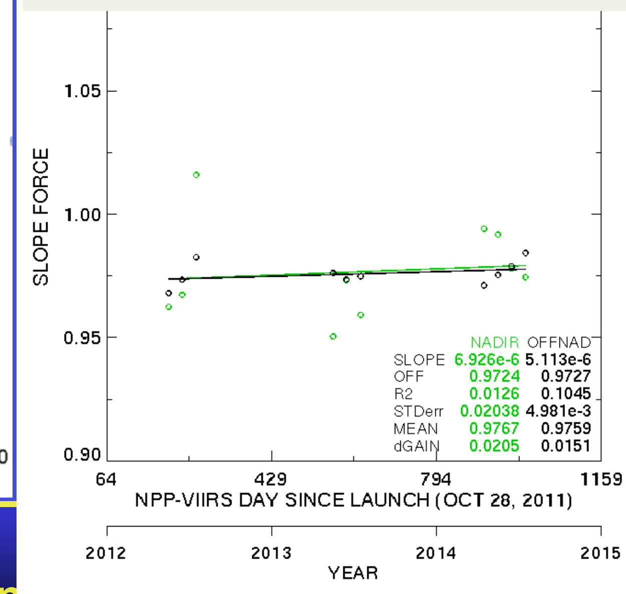
- Aqua-MODIS and NPP-VIIRS inter-calibration use simultaneous nadir overpass (SNO) ray-matched events
- Regress monthly the MODIS and VIIRS 50-km radiance pairs for both nadir and off-nadir geometry
- MODIS collection 6 and VIIRS AS3100 NASA Land PEATE calibration

Aqua-MODIS and VIIRS SNO events





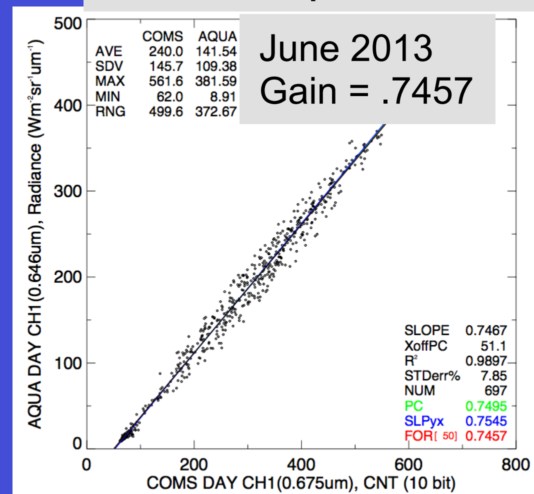
Aqua-MODIS B1 vs VIIRS M5 monthly scaling factors



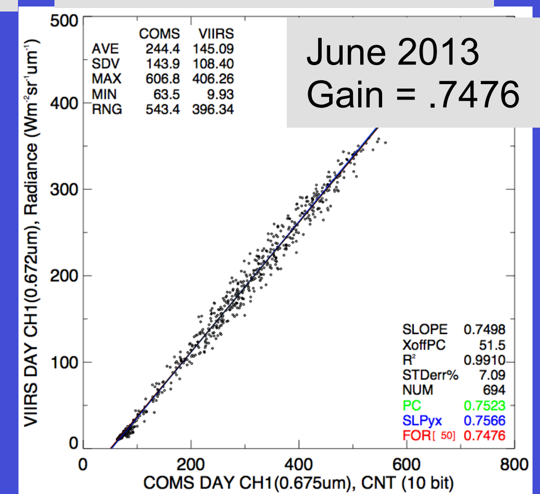
GEO/MODIS (B1) and GEO/VIIRS (M5) ray-matching calibration

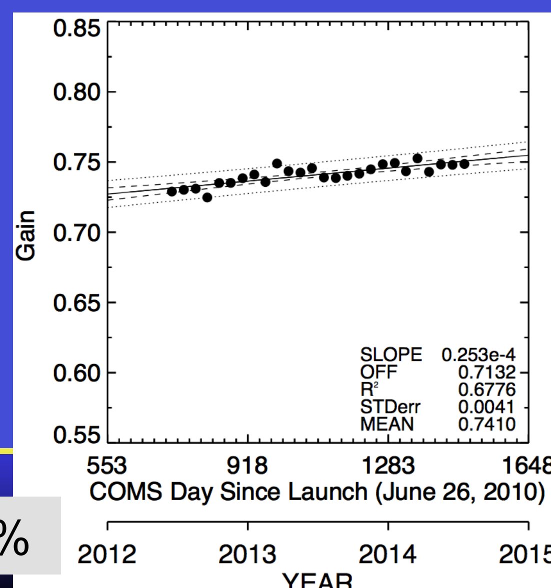
- 0.5° lat/lon grid COMS visible and Aqua-MODIS 0.65 µm radiances over COMS (TWP) equatorial domain
- Linearly regress monthly coincident angular matched COMS visible and MODIS 0.65µm radiance pairs
- Do the same for COMS/NPP-VIIRS

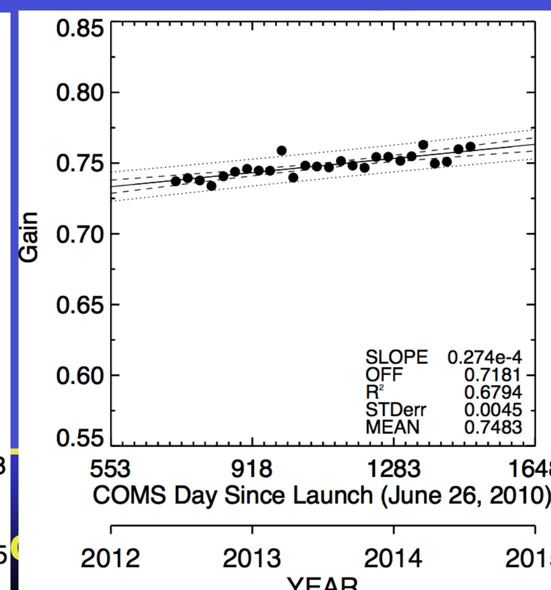
COMS/Aqua-MODIS



COMS/NPP-VIIRS

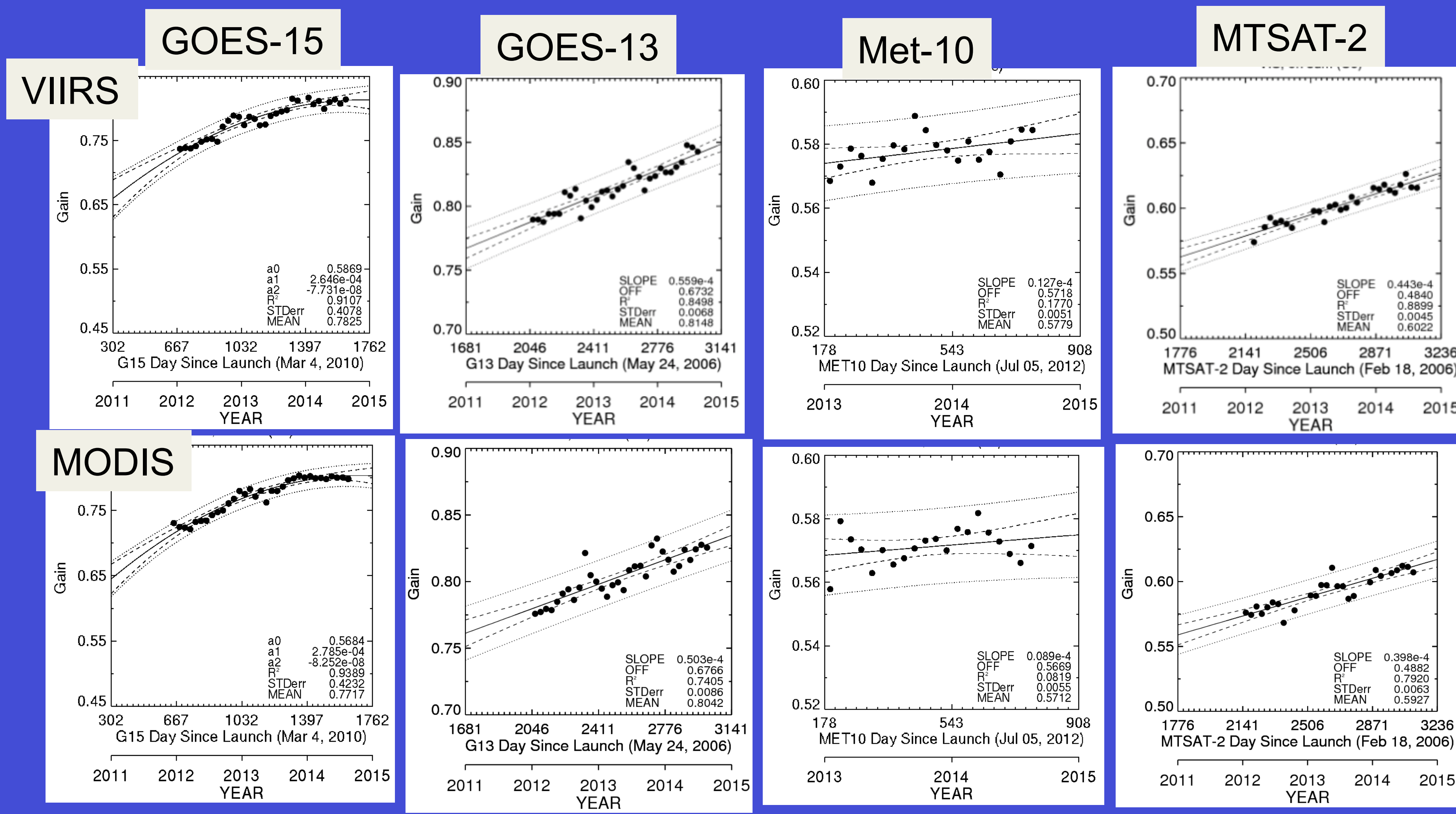






VIIRS(M5)/MODIS gain ratio = 1%

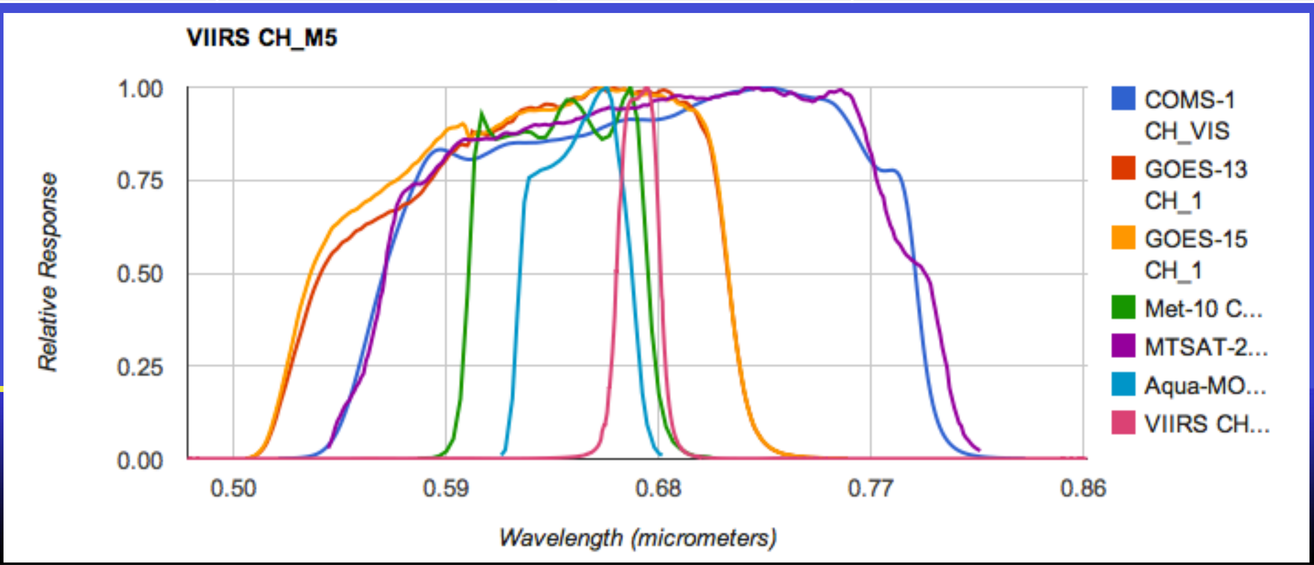
GEO/MODIS and GEO/VIIRS ray-matched gains



GEO/MODIS and GEO/VIIRS(M5) ray-matched gains

2012-2014 timeline	Geo/Aqua-MODIS mean gain	GEO/NPP-VIIRS mean gain	VIIRS(M5)/ MODIS(B1) ratio	Uncertainty Timeline + spectral
GOES-15	0.7717	0.7825	1.4%	0.6%+1.1%=1.3%
GOES-13	0.8042	0.8148	1.3%	0.8%+1.0%=1.3%
Met-10	0.5712	0.5779	1.2%	0.9%+0.3%=1.0%
MTSAT-2	0.5927	0.6022	1.6%	0.7%+1.5%=1.7%
COMS	0.7410	0.7483	1.0%	0.6%+1.5%=1.6%

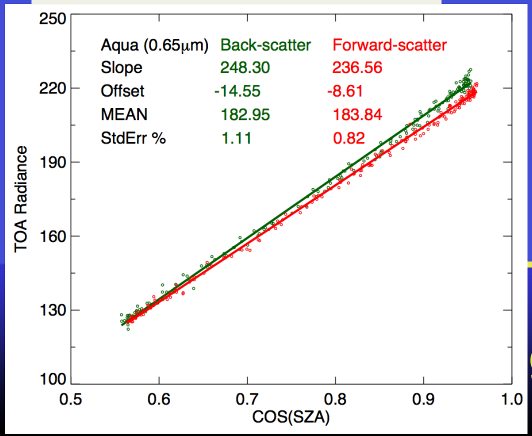
- The 5 GEOs give very consistent VIIRS/MODIS gain ratios even though the spectral bands are very different



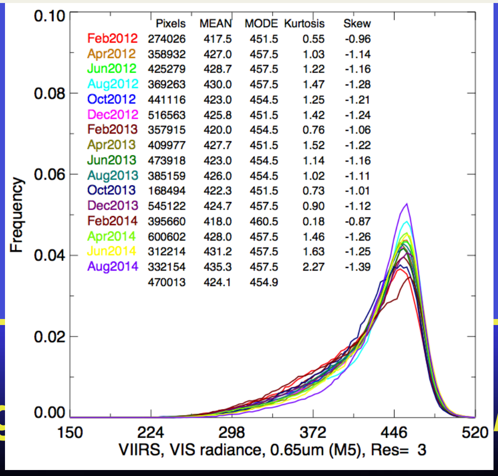
Libya-4 and DCC calibration approach

- Libya-4 TOA radiance (VZA<10°) is linearly regresssed as a function of SZA and scattering direction using 11 years of Aqua-MODIS observations
- Libya-4 VIIRS/MODIS ratio is then the VIIRS radiances divided by the corresponding MODIS radiance from Libya-4 MODIS model
- The VIIRS DCC ADM corrected monthly PDF mode radiance is divided by the corresponding MODIS PDF mode

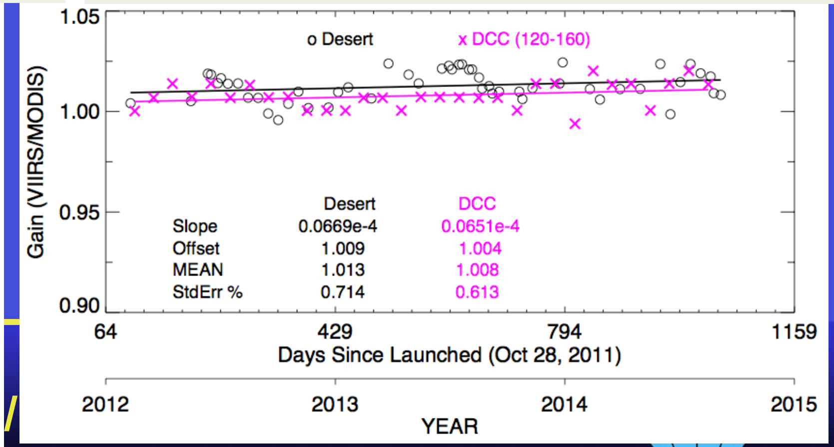
Libya-4 MODIS radiance model



VIIRS DCC monthly PDFs



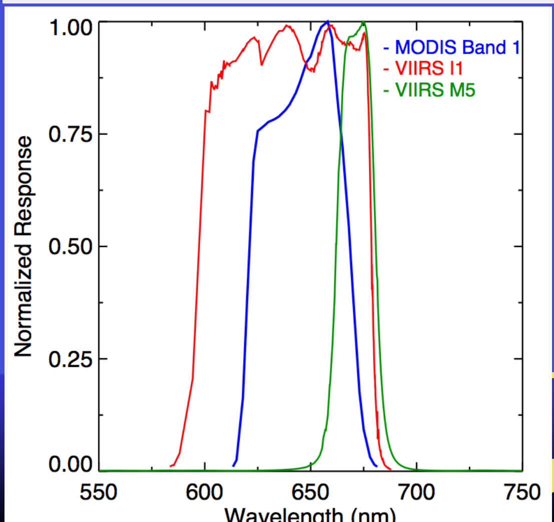
VIIRS/MODIS monthly gain ratios



MODIS to VIIRS radiometric scaling summary

- The NPP-VIIRS(M5)/Aqua-MODIS ratio is ~ +1.3%, whereas the NPP-VIIRS(I1)/Aqua-MODIS ratio is ~ -0.7%
- All calibration approaches give consistent results within their uncertainty (DCC and Libya-4 natural variability and angular and temporal mismatch for SNO and ray-matching)
- The uncertainty will decrease as NPP-VIIRS lifetime extends
- The predicted DCC and Libya-4 VIIRS stability is 1%/decade in 5 and 10 years respectively

MODIS and VIIRS spectral responses

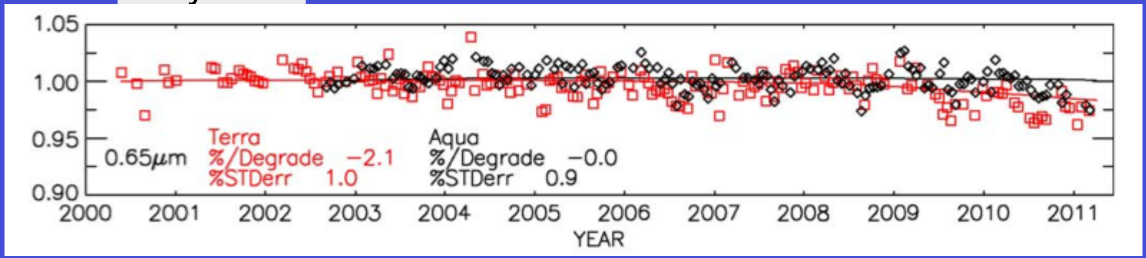


Method	VIIRS/MODIS ratio		Uncertainty (%)	
	I1	M5	I1	M5
SNO	NA	+2%	NA	1.7%
Desert	-0.4 %	+1.3%	1.3%	1.3%
DCC	- 1 %	+0.8%	1.1%	1.1%
GEO	NA	+1.3%	NA	1.3%

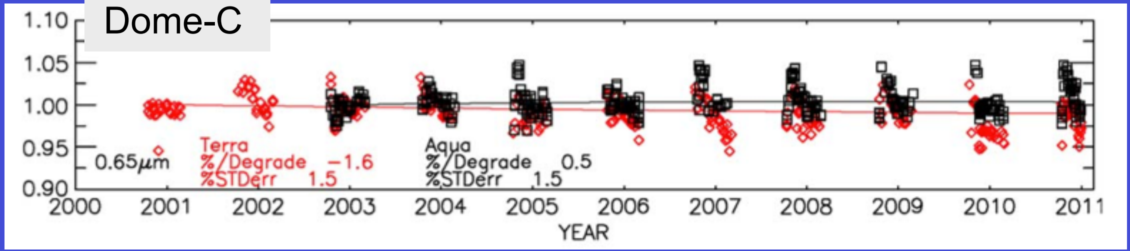
MODIS C5 calibration stability

- CERES Edition 4 MODIS radiances are based on MODIS collection 5 radiances

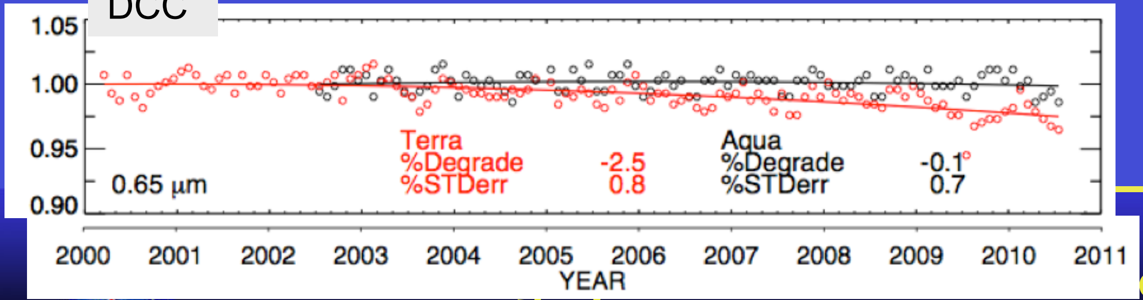
Libya -4



Dome-C



DCC



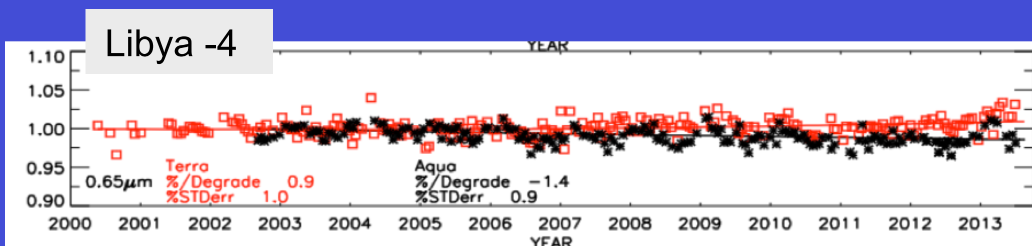
Wu et al. 2013, TGRS

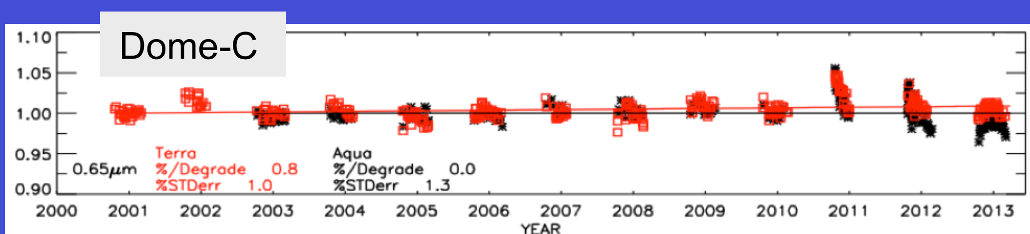
Terra-MODIS band 1 (0.65µm) Collection 5 has two calibration anomalies

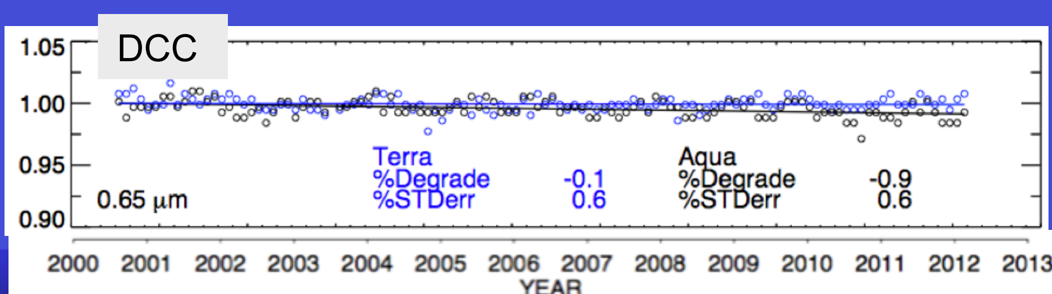
- Nov 2003 1% drop due to the solar diffuser doors being stuck in the open position
- March 2009 1.5% drop when the MODIS calibration team recalibrated the solar diffuser monitor. Collection was in forward processing mode
- These two anomalies are removed in Collection 6
- Aqua Collection 5 had a minor adjustment in March 2009

MODIS C6 calibration stability

- MODIS collection 6 has removed the solar diffuser and SDSM recalibration







C6 Trend %/lifetime	Terra	Aqua
Libya-4	0.9 (1.0)	-1.4 (0.9)
Dome-C	0.8 (1.0)	0.0 (1.3)
DCC	-0.1 (0.6)	-0.9 (0.6)

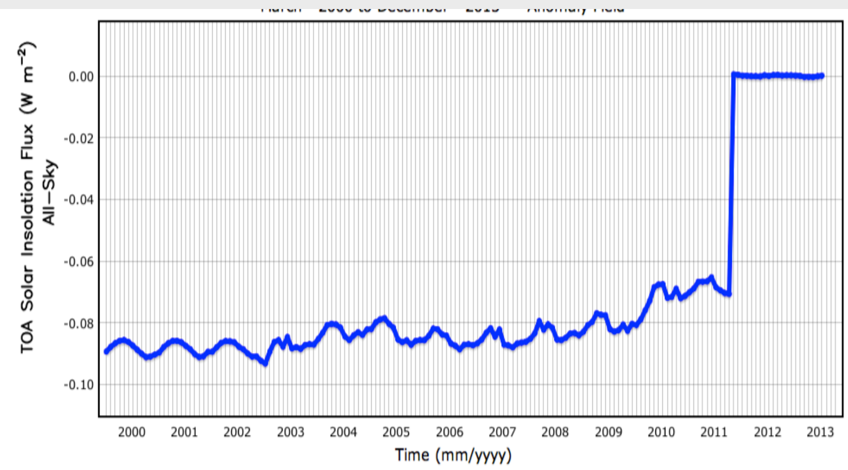
- It seems that Terra is getting slightly brighter over time, whereas Aqua is getting darker

Doelling et al. 2014, TGRS, submitted

Solar Incoming

- Solar incoming is based on SORCE V-15 absolute calibration
  - RMIB composite (DIARAD/VIRGO) solar incoming used after July 1, 2013 to present
  - Any SORCE/RMIB version calibration updates are normalized between March 2003 and Feb 2008 SORCE V15
- Not weighting number days in a month causes a +0.036 (+0.045 leap year) Wm^{-2} annual global mean bias (truth 365.25 day year)
- Not using a 365.25 day year causes a -0.008 (+0.024 leap year) Wm^{-2} annual global mean bias

EBAF Ed2.7 composed of SORCE V10-V15
Normalizing to V15 removed the -0.09 Wm^{-2} bias

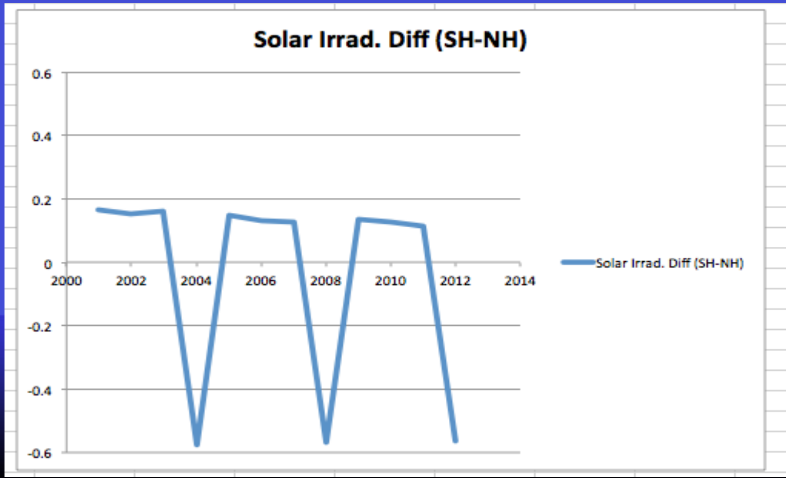


Check the oblate spheroid assumption
Oblate 1361/4.0034 = 340.0 Wm^{-2}
Spherical 1361/4.0 = 340.25 Wm^{-2}
Theoretical difference = 0.25 Wm^{-2}

TISA Oblate (1361) = 340.001 Wm^{-2}
TISA Spherical = 340.293 Wm^{-2}
TISA difference = 0.292 Wm^{-2}

Solar Incoming

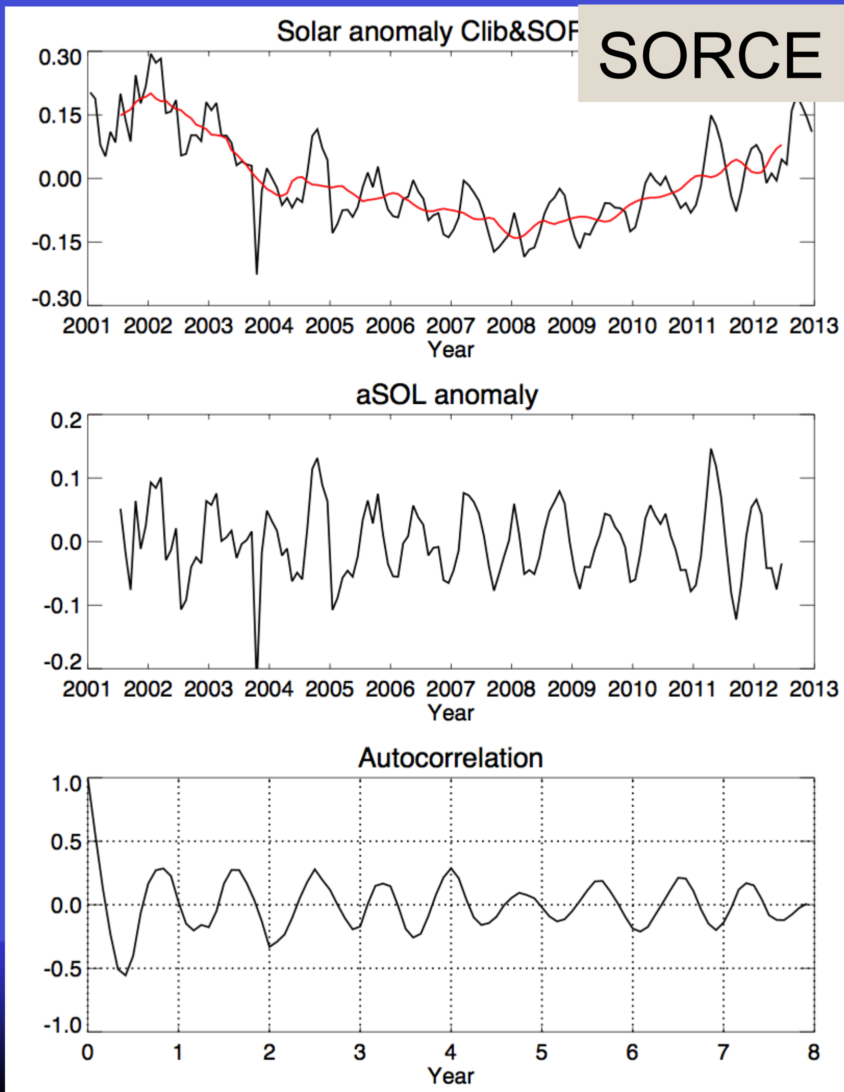
- EBAF and SSF1deg and SYN1deg-lite Ed2.8 products have a coding error, where the midpoint hourly solar incoming flux was used to compute the daily mean flux
  - Increased the annual global solar incoming flux by 0.144 Wm^{-2}
- SYN1deg Ed3 solar incoming used integrated hourly solar incoming fluxes, however hourboxes with cos(SZA)<0.01 were set to 0.0
  - This decreased the annual global solar incoming flux by 0.4 Wm^{-2}
- NH/SH global annual asymmetry bias, is due to the calendar year definition, and is due to the declination angle



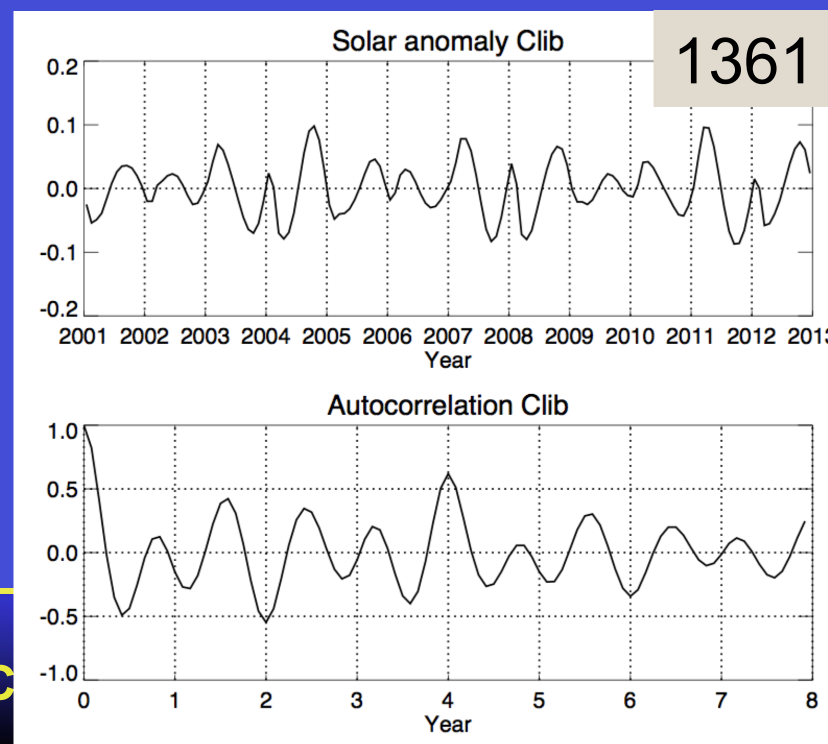
SH-NH (Wm-2)	365.25 day Year	Calendar Year
2001	0.027	-0.162
2002	0.029	-0.160
2003	0.012	-0.178
2004	0.019	0.585

Solar Incoming Anomaly Oscillations

- A user questioned why there was 1.25 oscillations/year in the deseasonalized monthly global solar incoming flux. The amplitude ~ 0.1 out of 340.0 Wm-2 ~0.03%



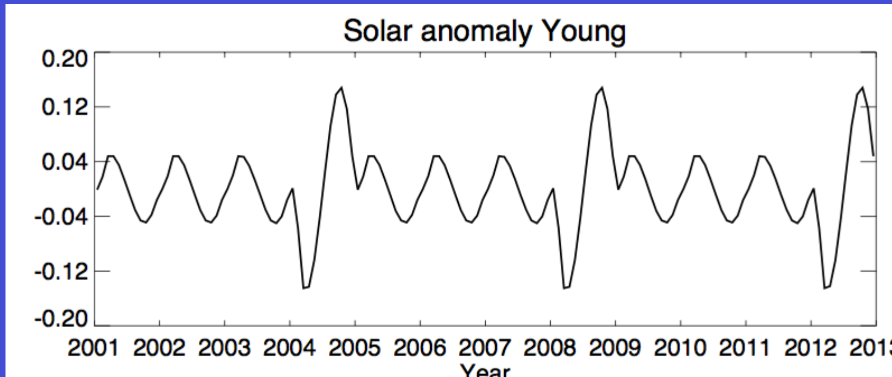
The oscillations are not associated with SORCE

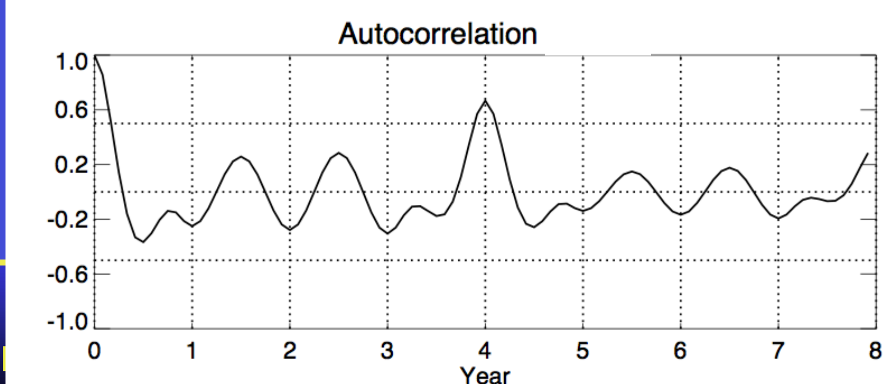


Solar Incoming Anomaly Oscillations

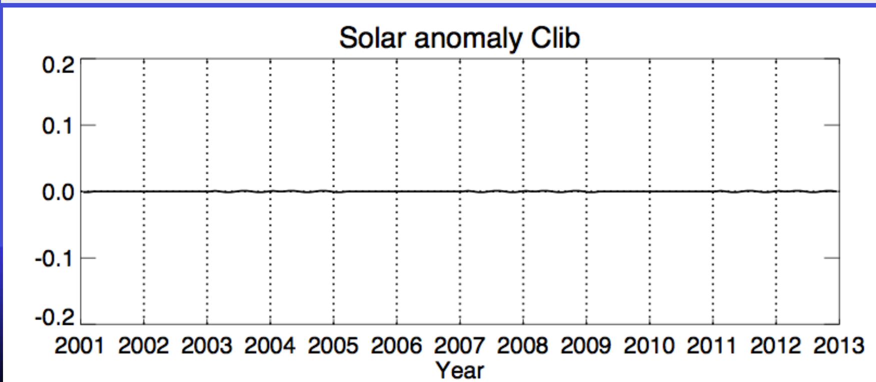
- CERES distributes fluxes based on calendar months
- If the deseasonalization were performed using 365.25/12 day interval months than the oscillations would not appear
- The Earth-sun distance correction factor varies by a few days from year to year

Now suppose I have the same daily Earth-Sun distance factors every year except for the leap year where I add an extra day at the end. The extra day in February then shifts the rest of the month in the leap year causing the anomaly





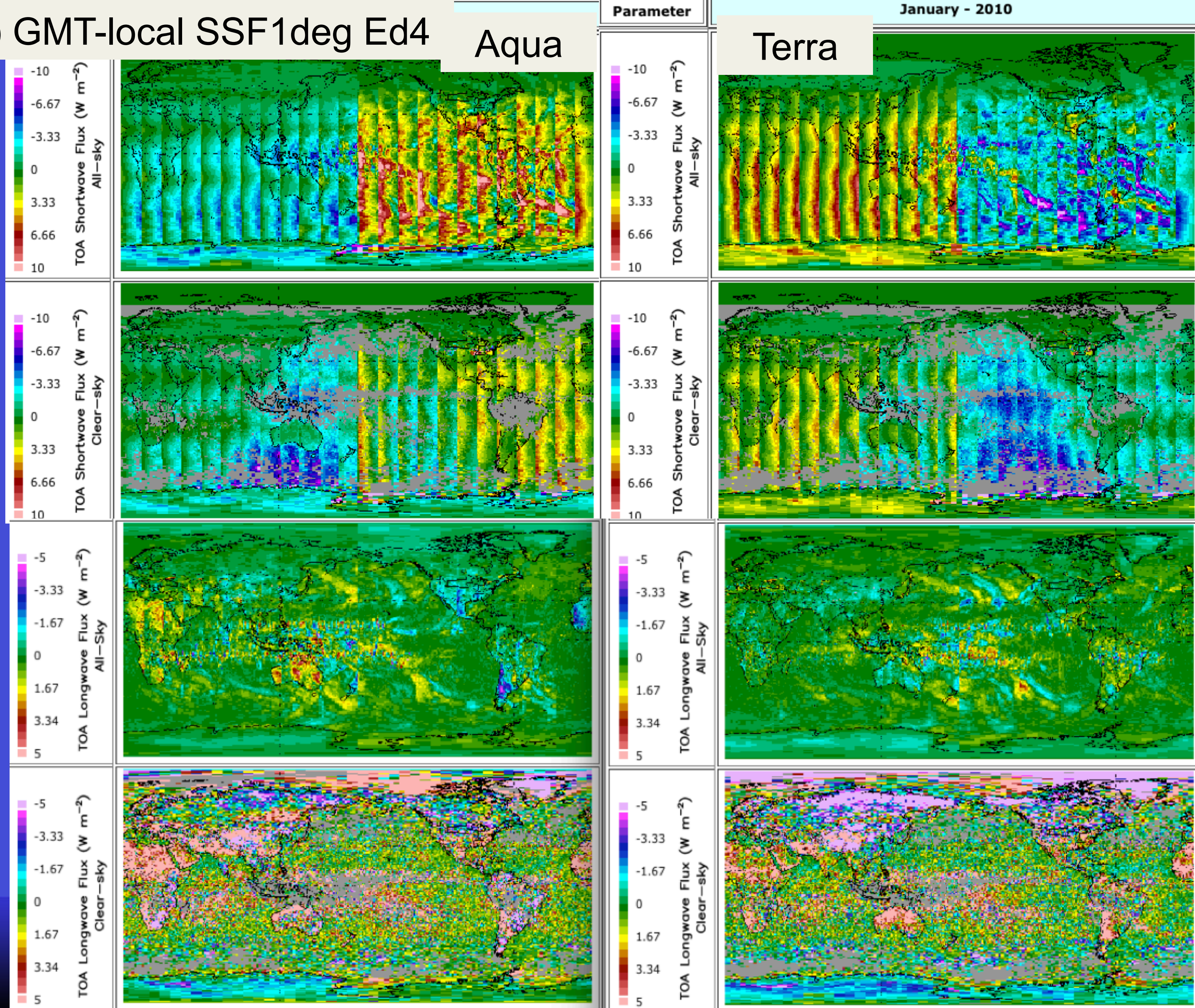
Set the Earth-Sun distance factor=1.0
Oscillations disappear



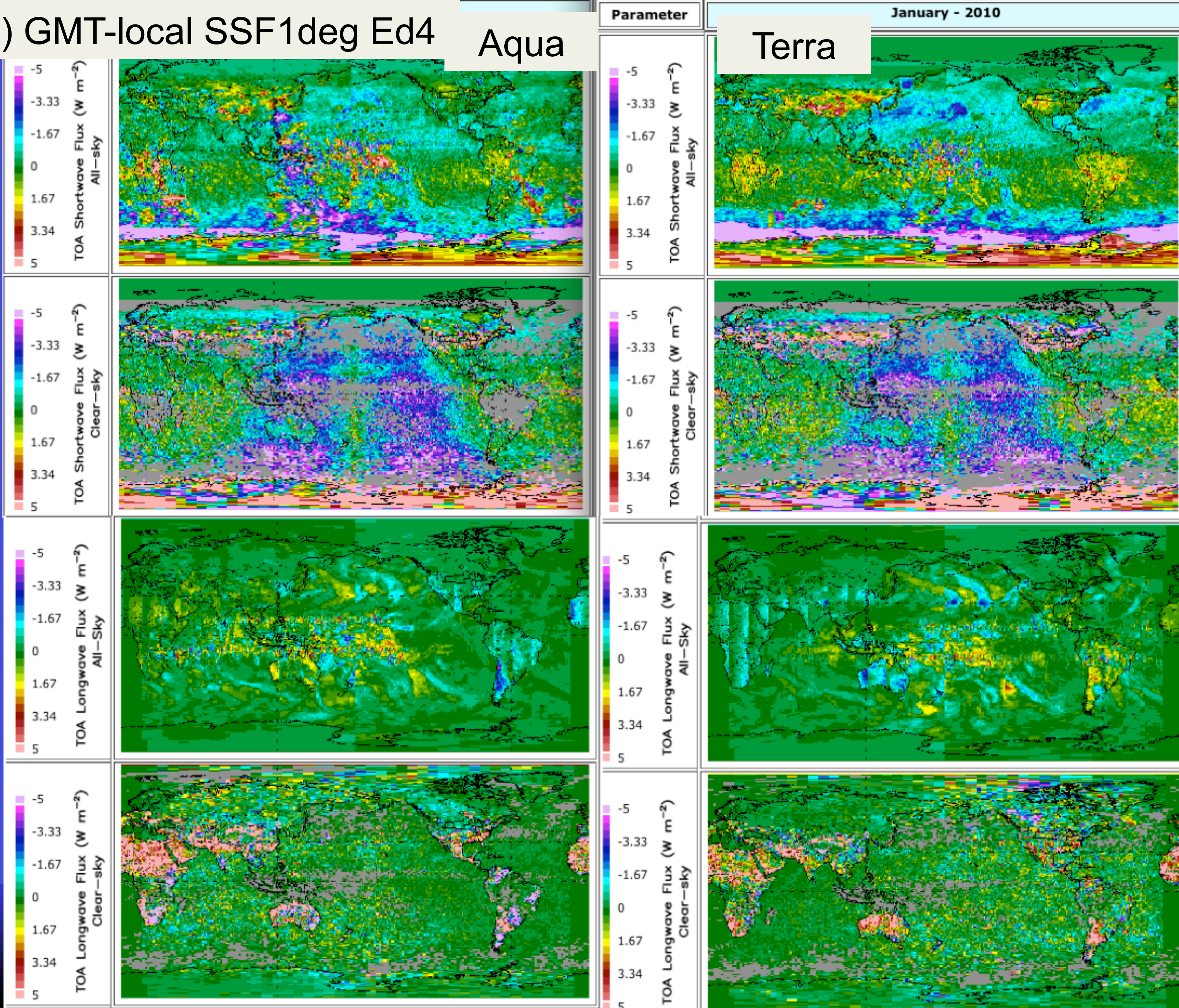
SSF1deg Ed4 Delivery

- For Edition 4, the SSF1deg input had both cloud, ADM improvements and the SSF1deg code was converted from local time hourboxes to GMT defined hourboxes
- The SSF1deg code was validated by comparing local time (Ed3) and GMT (Ed4) monthly means using the same Ed4 inputs
- The code was put to the test
  - The number of CERES clear-sky footprints was reduced
  - The greatest challenge was how to handle a local clear-sky day split between two different GMT days when deriving daily mean fluxes
- Many historical code artifacts were discovered
- The coding needs to be improved for easy debugging, parameter scalability, and modularity
- Code to be delivered shortly, need to fix some clear-sky SW flux issues

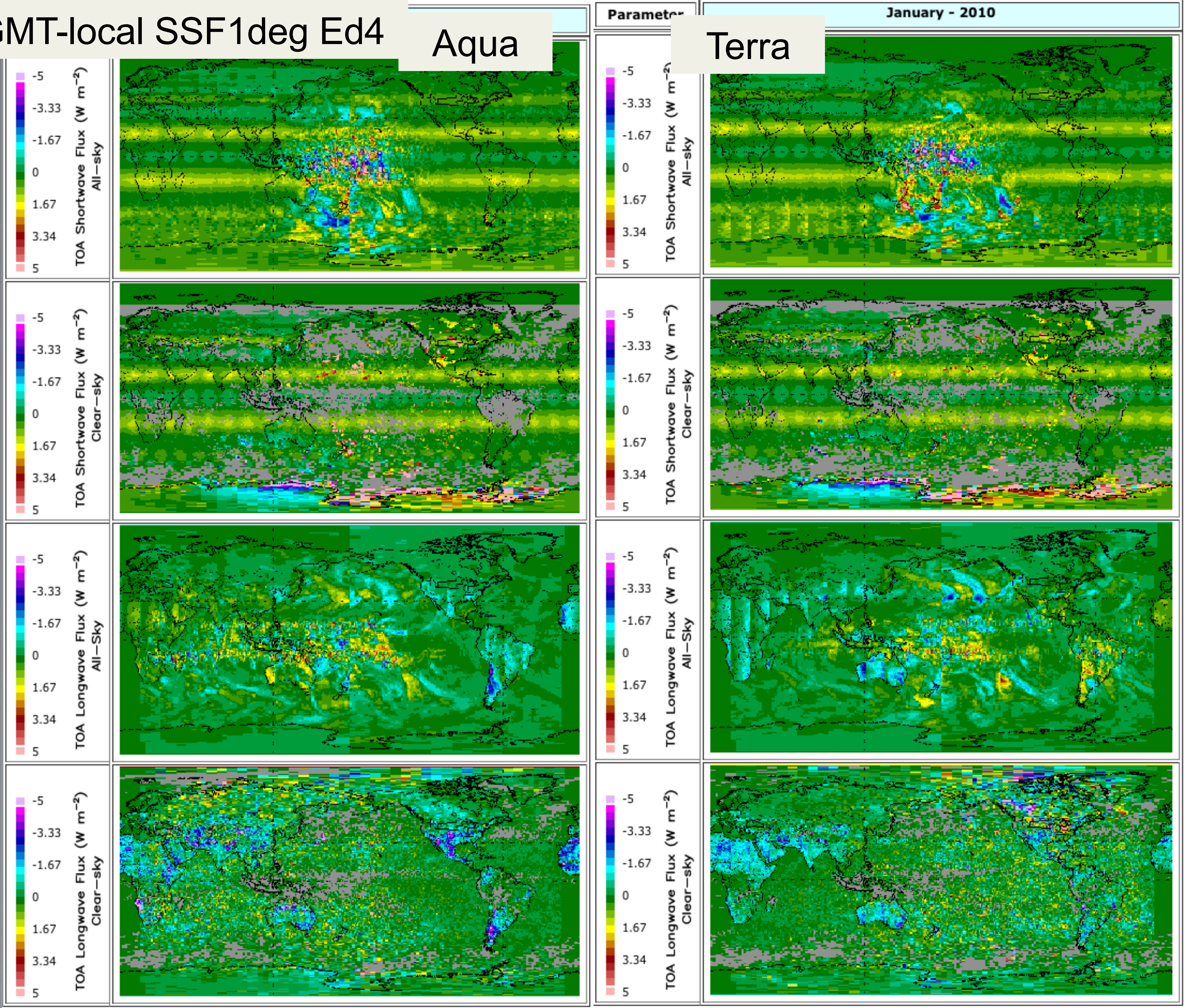
(1) GMT-local SSF1deg Ed4



(2) GMT-local SSF1deg Ed4



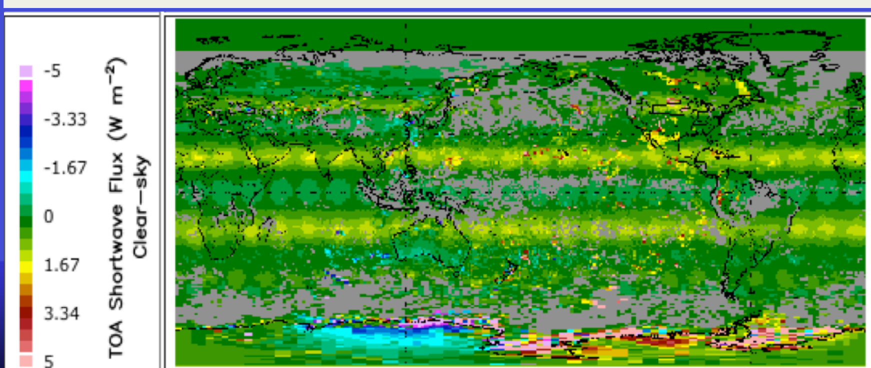
(3) GMT-local SSF1deg Ed4



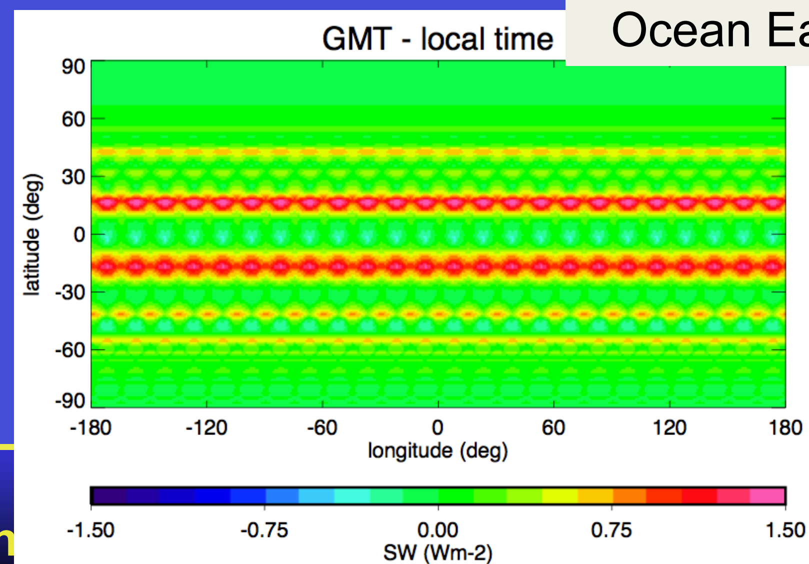
Validate that SW horizontal stripes are due to GMT and local time differences

- Assume an ocean Earth
- Compute SW hourly flux from clear-sky ocean directional model based on the hourly SZA for January 2010
  - GMT uses integrated SZA for the hourbox
  - Local time uses instantaneous center hourbox SZA
- Compute GMT and local time monthly regional SW fluxes
  - For GMT simply average hourly fluxes to compute daily means
  - For local time compute daily albedo, weighted by cos(SZA), and apply integrated daily solar incoming flux

Jan 2010 Aqua GMT- local time



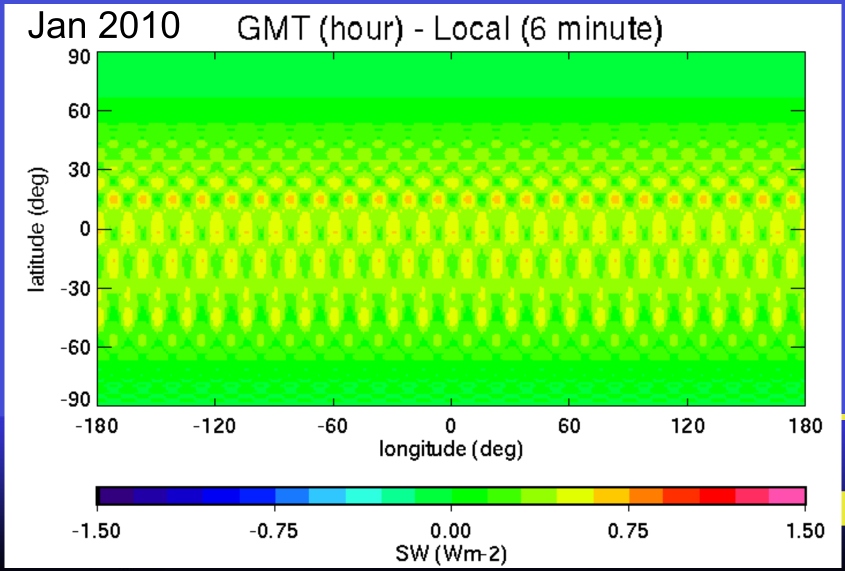
Ocean Earth



What is the magnitude of the Ed4 GMT hourbox discretization bias in the SW?

- The horizontal stripes are a result of the discretization of the number of time increments used during the day
- Ed4 uses 1-hourly time steps
- Assume 6 minute local time increments as truth and compare the GMT hourly vs truth monthly SW
- Consider 30 minute increments for Ed5

Clear ocean Time (min)	Global annual SW difference	Greatest regional daily SW flux annual range
60	0.37	-0.93 to 0.59
30	0.08	-0.21 to 0.15
15	0.02	-0.08 to 0.05

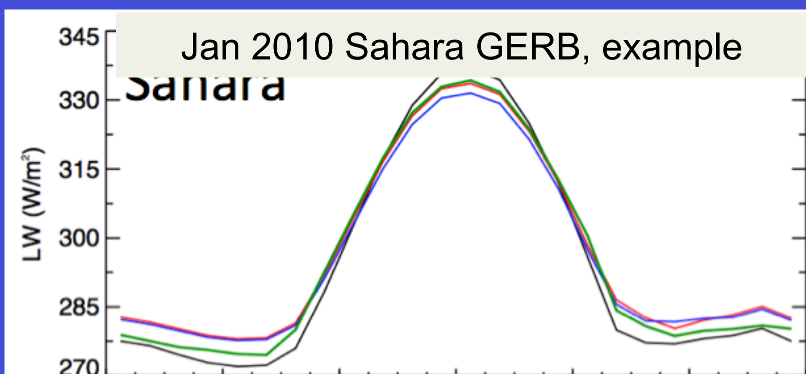


Mostly cloudy ocean Time (min)	Global annual SW difference	Greatest regional daily SW flux annual range
60	0.21	-0.64 to 0.37
30	0.05	-0.17 to 0.11
15	0.01	-0.05 to 0.03

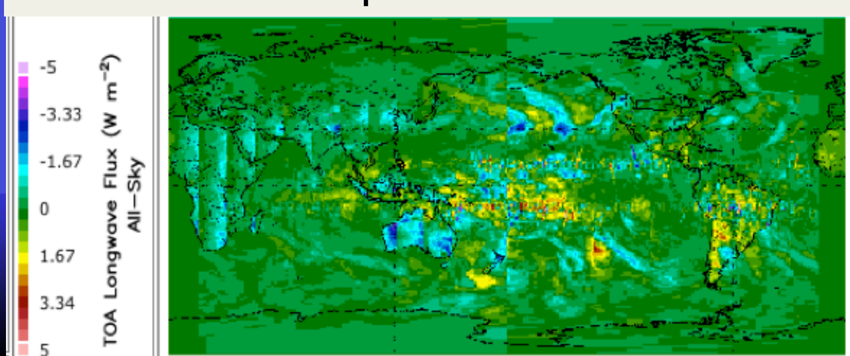
What causes the land clear-sky LW land longitude striping?

- Use GERB example LW night = 275, LW noon = 335, halfday=6 hours
- Compute daily means by changing number of daily time steps from 60 to 6 minutes is 0.05 Wm^{-2}, This is not the issue
- Observed LW is placed in the center of hourbox, if observation is moved by ±30 minutes, the longitude daily mean variation is ~2.5 Wm^{-2}

Jan 2010 Sahara GERB, example

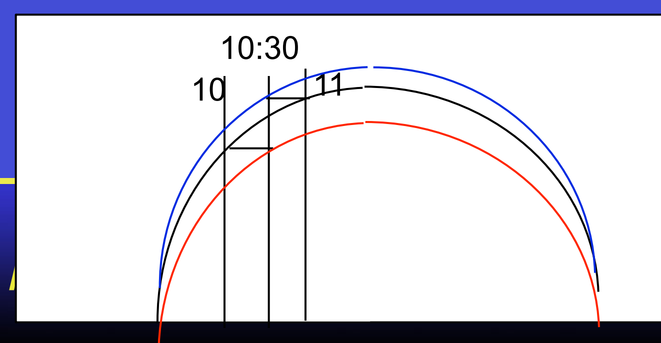


Jan 2010 Aqua GMT- local time



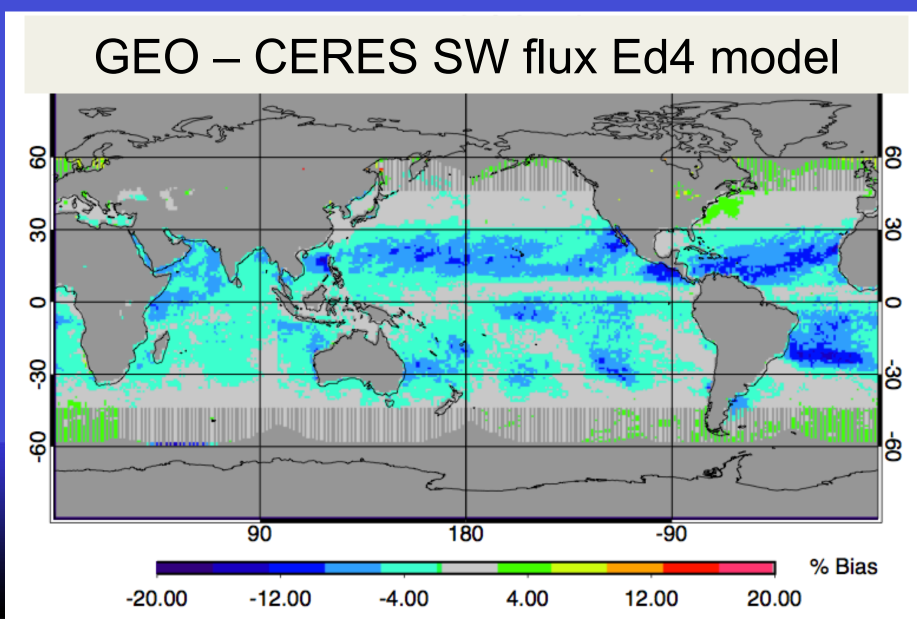
11AM-10AM daily flux difference (Wm^{-2})

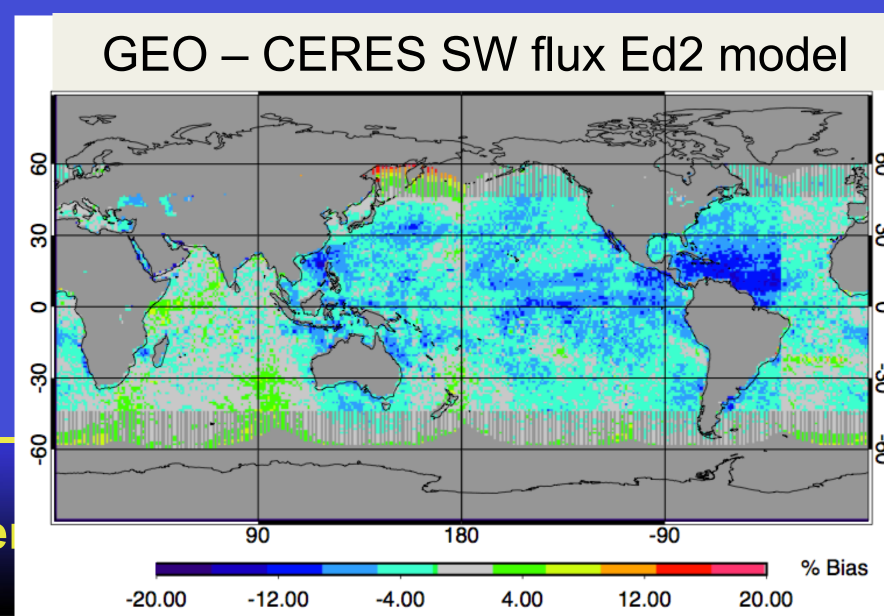
Time (min)	10:30AM	9:30AM
60	2.24	3.57
30	1.12	1.78
15	0.56	0.89



SW NB to BB

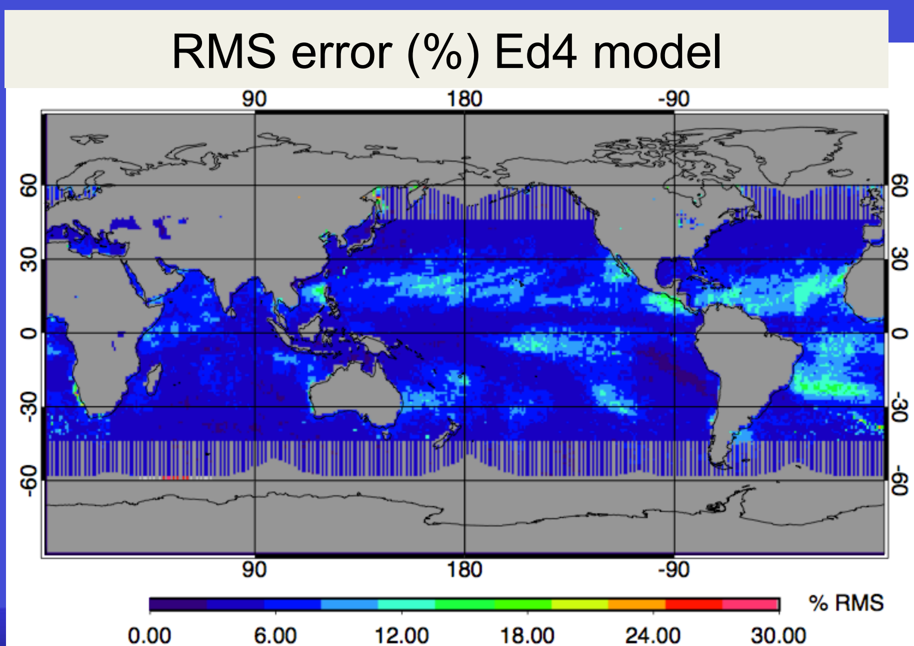
- For Edition 3 the GEO visible radiances were converted to MODIS equivalent radiances using theoretical models. Then apply SSF MODIS to SW empirical models.
- For Edition 4 over ocean the GEO visible radiances are converted directly to SW using theoretical radiances
  - The 32 spectral band theoretical radiances are easily convolved with GEO imager spectral responses for both historical and future imagers
- Test by comparing GEO SW fluxes with Terra and Aqua CERES fluxes within 30 minutes for Jan 2010 before normalization

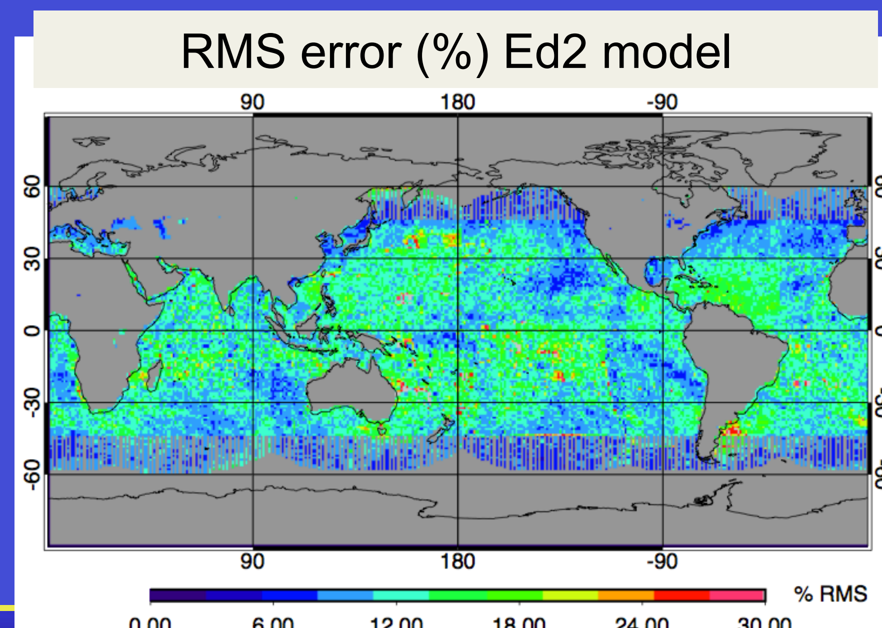




SW NB to BB

- The Ed4 method over ocean has reduced the RMS error by half (after normalization), while maintaining similar biases as Ed3
- The land and desert clear-sky radiative transfer modeled radiances are limited by the available surface spectral ADM data
  - Spring and summer prairie, alkaline and sand

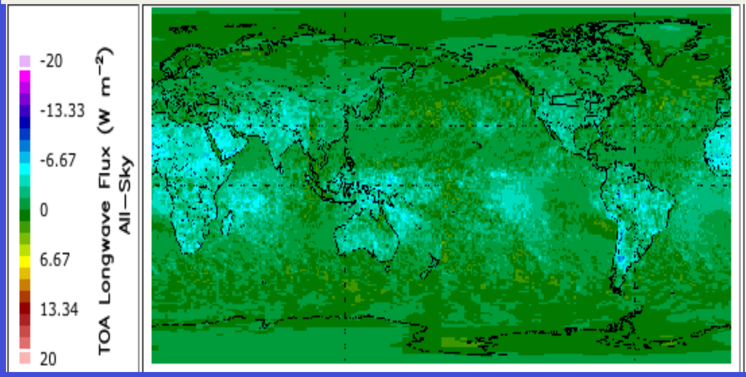




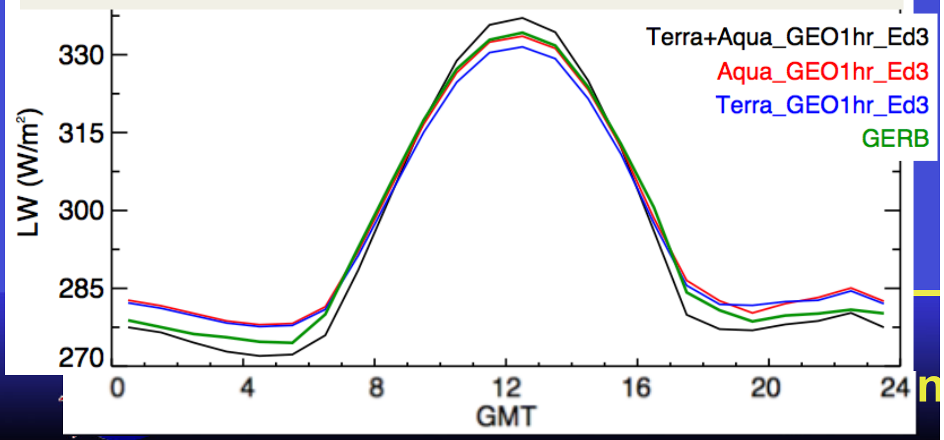
LW NB to BB

- Normalize the GEO imager 11µm and 6.7µm temperatures with Aqua-MODIS
- Apply Aqua-MODIS 11µm (WN) and 6.7µm (WV) to CERES LW flux model based on SSF, Terra-MODIS had noisy WV
- 5° by 5° LW GEO/CERES regional normalization (similar to SW)
- Ed3 used 11µm to LW apriori parameterization and instantaneous normalization
- Compare Ed4 and Ed3 flux using GERB as truth

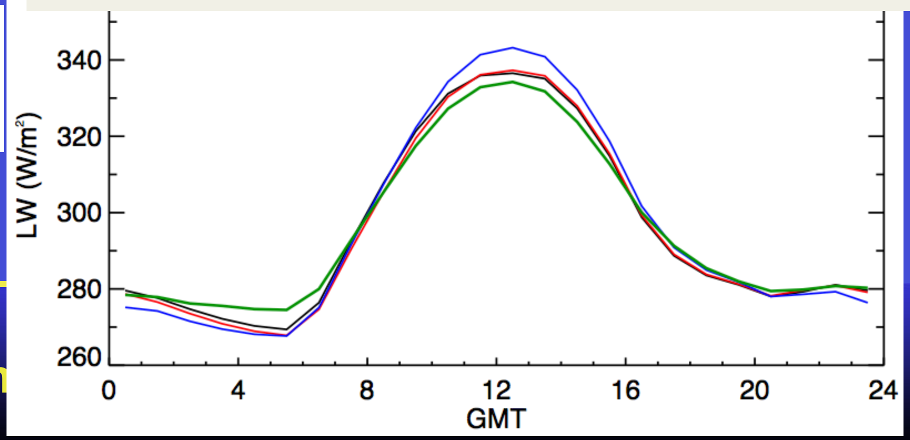
Ed4-Ed3 Jan 2010 LW flux



Ed4 Sahara desert, Jan 2010



Ed3 Sahara desert, Jan 2010



LW NB to BB

Jan 2010 (%)	Bias	monthly	daily	3hour	1hour	M3hour	M1hour
Ed4 1hr reg norm	0.14	0.59	1.48	2.43	2.77	0.92	1.07
Ed3 1hr reg norm	0.19	0.53	1.76	3.19	3.55	1.03	1.20
Ed4 1hr	0.20	0.99	1.67	2.58	2.92	1.20	1.33
Ed3 1hr	0.04	2.22	2.86	3.88	4.19	2.20	2.32
Ed4 3hr reg norm	0.02	0.83	1.52	2.63		1.37	
Ed3 3hr reg norm	0.23	0.81	1.87	3.45		1.61	
Ed4 1hr inst norm	0.22	0.48	1.67	2.99	3.31	0.89	1.07

- Ed4 approach requires smaller normalization corrections
- Ed4 reduces the daily, and higher temporal resolution RMS errors
- 5x5 regional normalization and instantaneous normalization are similar at the monthly level, but regional normalization is improvement for higher temporal resolutions
- The hourly GEO input decreases the monthly diurnal RMS most

LW NB to BB

Jan 2010 (%)	Bias	monthly	daily	3hour	1hour	M3hour	M1hour
Ed4 1hr reg norm	0.14	0.59	1.48	2.43	2.77	0.92	1.07
Ed4 1hr reg norm Aqua	0.30	0.69	1.53	2.45	2.79	0.97	1.12
Ed4 1hr reg norm Terra	0.05	0.66	1.51	2.45	2.79	0.95	1.11
Ed3 1hr reg norm	0.19	0.53	1.76	3.19	3.55	1.03	1.20
Ed3 1hr reg norm Aqua	0.20	0.77	2.34	3.55	3.88	1.06	1.22
Ed3 1hr reg norm Terra	0.29	0.61	2.18	3.52	3.86	1.17	1.32

- Ed4 greatest improvement is the consistency between single and dual satellite dataset LW fluxes
- This is important once CERES remains in an afternoon orbit only satellite after the failure of Terra
- Ed3 single satellite dataset daily and high temporal resolution RMS errors are much higher than for Terra and Aqua dataset

TISA future work

- Deliver Edition 4 codes
  - SSF1deg and TSI/SYN1deg (Oct 2014)
  - Finalize GEO bad scan line removal and GEO cloud retrieval Ed4 production processing (Oct 2014)
  - SSF1deg Ed3 to carry over until Ed4 is in forward processing mode, Edition 4 code modified with Ed 3 inputs (Nov 2014)
  - Update SSF1deg Ed4 improvements into the EBAF code (Nov 2014)
  - ISCCP-D2like Ed4 (Jan 2015)
  - Fluxbycloudtyp Ed4 (March 2015) processed 10-years offline
  - Place all Edition 4 products on the CERES ordering and visualization tool
  - Write Ed4 product DQS
  - Validate GEO temporal averaging with GERB and Megha-tropique fluxes
  - Publish Ed4 improvements, GEO LW NB to BB
- TISA production code review
  - Increase code maintainability designed for debugging ease, parameter scalability, code modularization, and develop new algorithms within environment

TISA future work

- Test incorporation of GEO 3rd generation imagers into TISA framework
  - Himawari-8 launches on Oct 7, 2014 has a 16 channel imager allowing MODIS quality GEO cloud properties
  - GOES ABI (2016) and MTG (2019), 16 channel, 1-km VIS, 2-km IR, 10’ FD
  - Set up GEO multi-channel calibration with VIIRS as reference
  - GEO NB to BB will be similar to MODIS to CERES NB to BB, use CERES SSF to develop coefficients, scale GEO channel radiances to MODIS/VIIRS equivalent channels
  - GEO clouds should be of similar quality to MODIS, test direct application of CERES ADMs
- VIIRS does not have WV channel
  - Test apriori Aqua-MODIS SSF WN+WV to LW coefficients against monthly coefficients
  - Test IASI spectral band adjustment factors to scale GEO IR to MODIS equivalent
- Test half-hourly temporal averaging to remove small zonal systematic biases
- Use GSICS GEO IR calibration coefficients calibrated against IASI